

1900  
K81

KOCH

Illinois Coals

Chemistry

M. S.

1900

Learning and Labor.

LIBRARY

OF THE

University of Illinois.

CLASS.

BOOK.

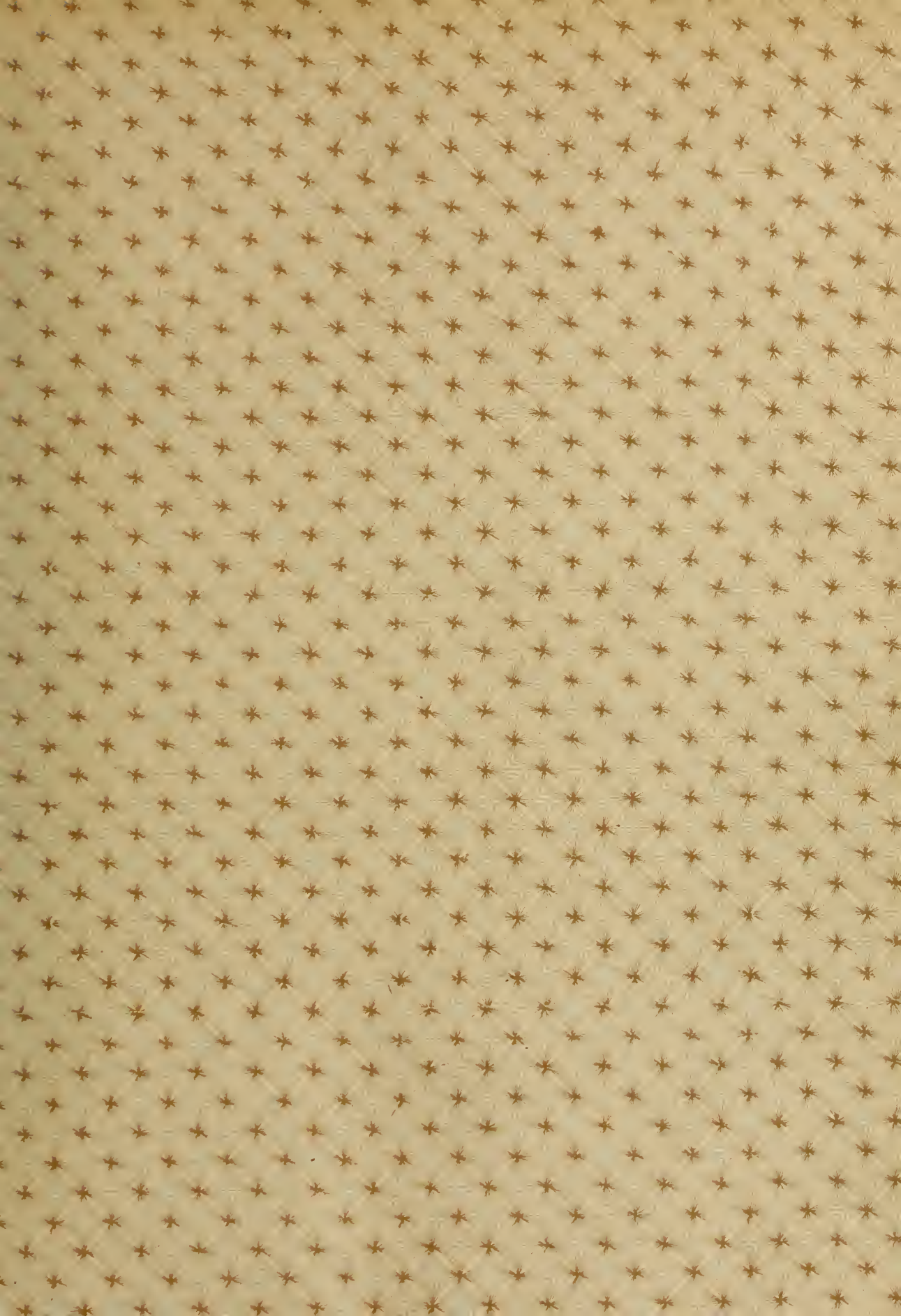
VOLUME.

1900

K 81

Accession No.







A Study of Illinois Coals  
WITH  
A New Method for Determining  
Their Calorific Value

BY

FRED CONRAD KOCH B. S. '99

---

THESIS

FOR THE DEGREE OF  
MASTER OF SCIENCE IN CHEMISTRY

---

UNIVERSITY OF ILLINOIS

PRESENTED JUNE 1900



1900  
K81

UNIVERSITY OF ILLINOIS

June 1 1900

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

F. O. Koch

ENTITLED *A Study of Illinois Coals*  
*with a New Method for Determining their*  
*Calorific Value -*

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF *Master of Science in Chemistry*

*J. W. Parr*

HEAD OF DEPARTMENT OF *Applied Chemistry,*



Digitized by the Internet Archive  
in 2013

<http://archive.org/details/studyofillinoisc00koch>



Of the 600,000,000 tons of coal mined in 1897, Great Britain supplied thirty-four per cent., the United States thirty and Germany eighteen per cent.(1). Of this home production of 180,000,000 tons Pennsylvania supplied 54,600,000 tons or thirty per cent; Illinois, 20,000,000 tons or eleven per cent; West Virginia, 14,300,000 tons or seven per cent., and Ohio 12,200,000 tons or six per cent.(3). We say that Illinois produced 20,000,000 tons in 1897, that is, it is equal to the amount produced in 1896 by all the other countries except Great Britain, United States, Germany, France, Austria-Hungary, Belgium, Russia and Japan, or in other words Illinois produced almost twice as much coal as Russia which ranks seventh in the list of the greatest coal producing countries (2).

Below is given a table showing the coal-mining statistics of Illinois for the years 1882 to 1897 inclusive:-

Year	No. of Mines	No. of Men Employed	Total Product in Tons.	Total Tons of Lump Coal	Total Tons of Other Grades
1882	704	20 290	11 017 069	9 115 653	19 015 06
1883	639	23 939	12 123 456	10 030 991	20 924 56
1884	741	25 575	12 208 075	10 101 005	21 070 70
1885	778	25 946	11 834 459	9 791 874	24 025 85
1886	787	25 846	11 175 241	9 246 435	14 288 06
1887	801	26 804	12 423 066	10 278 890	21 441 76
1888	822	29 410	14 328 181	11 855 188	24 724 93
1889	834	30 076	14 017 298	11 597 963	24 193 35
1890	936	28 574	15 274 727	12 633 364	2 636 363
1891	918	32 951	15 660 698	12 960 224	2 700 474
1892	839	33 632	17 862 276	14 730 963	3 131 313
1893	788	35 390	19 949 564	16 112 899	3 836 655
1894	836	38 477	17 113 576	13 865 284	3 248 292
1895	874	38 630	17 735 864	14 045 962	3 689 902
1896	901	37 032	19 786 626	14 210 024	5 576 602
1897	853	33 788	20 072 758	14 672 24	5400 517

THE UNIVERSITY OF CHICAGO  
LIBRARY  
1207 EAST 58TH STREET  
CHICAGO, ILL. 60637  
U.S.A.  
TEL: (312) 937-1234  
FAX: (312) 937-1234  
WWW.CHICAGO.EDU  
CHICAGO, ILL. 60637  
U.S.A.



This enormous consumption by no means accurately represents the amount of energy actually used for domestic and industrial purposes. It is by no means making an exaggerated statement if we say that the amount of energy utilized is never as much as ten per cent. of the entire energy represented by the coal. But three per cent. of the energy in our coal-beds is ever realized for useful work (3). How is all this waste brought about? The causes are numerous and can be classified thus:-

(1). Loss in mining,

(a) In the mine

(b) Culm

(c) Slack

(2). Loss in combustion,

(a) Imperfect combustion

(b) Utilization of heat

(c) No saving of by-products

(3). Waste in coking and gas manufacture,

(a) No saving of by-products

(4). Using fuel which, if properly treated, would be more efficient.

In mining coal there is a loss of seventy per cent. of the coal originally in the vein. This is due first, to the large amount of fine coal left in the mine, because it ordinarily does not pay to hoist it; second, to the amount left in the mine as pillars, floor, roof and walls, in order to render the mine safe (3). The fine coal left in the mine can be hoisted and after washing can be sold with profit. So too, much of the coal now left in the mine as pillars, etc., can be displaced by better





and, in the end, cheaper material (4).

Mountains of culm are found around most of the mines in the anthracite-coal district. For example, the amount of coal left as culm from the Wyoming, Lehigh and Schuylkill regions of Pennsylvania, has been estimated to be thirty-five per cent. of the total production up to 1893 in that region. This amounts to about 315,700,000 tons (5). So too, in the bituminous-coal fields are large amounts of screenings and slack coal wasted every year. Although the per cent. of coal sent to the culm and slack heaps is not as great as it has been, still much is left to be done.

As regards the burning of the culm coal John R. Wagner (6) states that the requirements are clearly understood, but the fulfillment of them is not. The culm banks contain as much as forty to seventy per cent available and marketable coal (7). This, so Edward H. Williams (7) states, may be utilized possibly first, by burning in the ordinary state; second, by reducing to an impalpable powder, and burning as dust; third, by combining with some substance to form briquettes. More than fifty patents have been issued to use the coal in the first way; some thirty patents involve the second method and more than a hundred patents have been issued for the manufacture of briquettes. One other, Nelson W. Perry (8) suggests the manufacture of water gas at the banks and the subsequent distribution through pipe lines. The best success has been obtained by washing the coal and then burning directly. J. R. Wagner (6) says the features involved in burning the small coal are:- first, under grate blast, produced by fan or by steam jet; second, large grate area; third, grate so con-



structed as to constitute a plane surface without narrow grooves or depressions where an appreciable amount of coal could lodge; fourth, a kind of grate that will admit of rapid and easy removal of ash or clinker; fifth, air spaces from one sixteenth to three sixteenth of an inch in diameter and not more; sixth, cleaning of fires without having the fire doors open for any length of time, also the dropping of the ash into a closed ash-pit; seventh, thin fires and frequent and careful firing, and eighth, reduction of draught over fire as the value of the fuel or the rate of combustion diminishes, this being effected by means of a damper in the flue or stack.

In the treatment of slack coal it is found that washing gives a good coal and is profitable to the mine-owner. This will be discussed more fully later on.

What does imperfect combustion bring about? The smoke nuisance. More perfect combustion without loss of heat can be brought about by a hot air blast or by the, Schlicht (9) combustion process. This process was patented in March 1896. By it the air is led to the place of combustion through the products of combustion, by a short deflector situated in or upon a stack or flue. The heat absorbed by the air from the products of combustion is saved and delivered to the combustion chamber. The result is said to be a practically perfect combustion of the gaseous portion of the fuel. Thus we see that here, the heat that would have been wasted has been utilized. Let us look at the following example given by Andrew Gillespie (10) to illustrate the utilization of what would be wasted heat and also the saving of by-products. The volume of gases coming from a blast furnace







during twenty-four hours is over 40,000,000 cubic feet. These gases are at about 300° Fahrenheit as they pass by the collecting main. The results obtained from a plant recently erected in connection with four furnaces, show that in addition to the usual out put of pig iron, the gas raises steam in seventeen large high-pressure boilers, heats the air in three regenerative stoves, distills the tar into oil and pitch and evaporates the waste liquor, while the recovered tar yields seven gallons of oil and eighty-six pounds of pitch and the ammonia liquor twenty-five and one-half pounds of ammonium sulphate per ton of coal put into the furnaces. The total recovery for 1895 from 92940 tons of coal carbonized in the four furnaces, amounted to 677,000 gallons of oil, 3550 tons of pitch and 1057 tons of ammonium sulphate.

In the manufacture of gas and in coking coal by the ordinary bee-hive ovens, much heat and all the by-products are lost. Within the last few years by-product ovens have been introduced into the United States. In the Solvay system, simplicity, low cost of construction, rapid gasification, recuperation of waste heat, larger and better yield of coke and the saving of by-products are claimed as compared with the bee-hive oven. One oven produces annually four times as much coke as a bee-hive oven, and the value of this coke added to that of the by-products is at least seven times the value of the ordinary bee-hive coke (11).

No doubt a great saving can be effected if we use the coals lower in ash, especially when we can obtain them at almost the same price. We not only pay for a noncombustible substance in buying ash, but we also waste heat by heating the ash. Also



some ash, especially that from coals high in sulphur, is very annoying, in that it clinkers on the grates. The importance of the per cent. of ash in fuel is well illustrated by J. V. Schaefer (12). He calculated that when a coke containing fifteen per cent. of ash is used in a blast furnace there are required seventeen per cent. of coke more than when a coke containing five per cent. of ash is used. The extra amount of limestone used in the furnace, to neutralized the silica in the ash would cost more than the washing of the coal used for coking.

From the foregoing we have an idea of what vast importance are the production of coal and its use. We also see what there is to do for the engineer and chemist in order to decrease the enormous waste. However, this is not all. Not all bituminous coals answer equally well for a certain purpose. Although two coals may be bituminous and approximately of the same chemical composition, still it does not follow that they should behave alike when treated similarly under the same conditions. This behaviour of different coals presents interesting and difficult problems for the chemist to solve. First let us consider the pure chemistry of coal before we enumerate some of these problems.

Some attempts have been made to show that coal is a definite compound or a mixture of similar chemical compounds. In 1879 E. Guignet (13) found that by treating bituminous coal with phenol about two per cent. is dissolved. He believed that bituminous coal always contains several wax - or rosin-like substances which are difficultly soluble, but which by treating with concentrated nitric acid yield oxy-picric acid. He finds that coal contains a cellulose-like substance which at higher temperatures







is acted upon by sodium and potassium hydroxides. Guignet has also shown that by treating bituminous coal with concentrated nitric acid, several water soluble substances, such as, oxalic acid and tri-nitro resorcinol, etc., are formed and that several insoluble hydrogen containing, nitrated, explosive products, soluble in caustic alkali, remain. Reinsch in 1835 (14) found a small amount of coal soluble in strong potassium hydrate solution, a spongy substance being precipitated on acidifying with hydrochloric acid. Kramer (15) (16) in 1887 and 1890 considered the coals as anhydrides of highly condensed glycols and glycolic acids and their oxy- and anido-derivatives. The analytical and thermochemical data, however, are lacking which would prove this. Luzi, 1893, (17) seemed to think that possibly coal is some derivative of graphitic acid. All that has been done to show that coal is of a definite character, supports the view that it consists of a mixture of organic substances with more or less mineral matter.

Our knowledge as to the condition of the sulphur in coal is also somewhat limited, all we know is that some sulphate and sulphide is present in most coal, but what condition the organic sulphur is in, we do not know. By James P. Kimball (18) it is found that the gases given off in coking contain the following sulphur compounds:-  $H_2S$ ,  $SO_2$ ,  $NH_4CNS$ ,  $NH_4HS$ ,  $CSO$ ,  $CS_2$  and  $HCNS$ . Thomas M. Drown (19) in 1881 found that on coking a coal, which was low in  $FeS_2$  and high in volatile combustible matter, the organic sulphur was removed to the extent of twenty to forty-five per cent. But, in coking a coal which was high in  $FeS_2$  and low in volatile combustible matter the sulphur present as  $FeS_2$  was removed, while the organic sulphur remained in the coke. It is



certainly very important to know how much sulphur will pass off with the volatile matter, if the coal in question, is to be used in the manufacture of gas. The removal of the sulphur from the gas, or the prevention of the sulphur getting into the gas, is a problem which interests the gas manufacturer.

Numerous approximate and ultimate analyses have been made of coking and non-coking coals, but no fixed rule has been found to hold true as regards the best composition of a coking coal. Fleck and Hartig (20) claim that in a good coking coal the ratio of the "disposable" hydrogen (or that portion which is in excess of the quantity required to form water with oxygen present) to carbon must represent more than forty to one thousand of carbon. This rule does not hold in all cases. Richard Thomas (21) claims that the fusing quality of a coal depends on the ratio of the hydrogen to the carbon; this should be about one of hydrogen to fifteen and six tenths of carbon. This rule also, does not hold. The only way to test a coal is to coke it in the oven to be used, as crucibles tests are not reliable (22). A good coking-coal must give a strong coke, which has a metallic luster and character, and which is low in sulphur (below one per cent.), phosphorus and ash. Here then is another interesting and important problem.

In general we can say that Illinois coals are not well suited for coking and can not be used profitably for the manufacture of gas. First, let us consider what has been done with regard to the manufacture of gas from Illinois coals.

The only literature found on the study of Illinois coals for the manufacture of gas was the work of Louie H. Smith (23). He studied the following coals:- Big Muddy, Odin Pea, DuQuoin,







Odin Lump, Assumption Lump, Assumption Block, Kinnandy, Lincoln, Athens and Sangamon of Illinois. These were compared with the Youghiogheny of Pennsylvania, Briar Hill of Ohio, and Cannel Coal. It was found that the yield of volatile matter was on an average equal to that of the Eastern coals. But in considering the following points:- quantity of gas, illuminating power, sulphur and cost, he found that the different coals varied greatly. Still it is the large amount of sulphur present in Illinois coals, that prevents their more general use in gas making. Smith (23) found the DuQuoin coal the lowest in sulphur, but its yield in gas was not as high as in the case of the Youghiogheny coal, while the illuminating power of the latter was also greater.

How can this sulphur be removed? With the present methods of removing sulphur from coal gas, the cost is too great and the extent of removal is by no means satisfactory. Some experiments have been made along the line of keeping the sulphur in the coke. Philippart in 1880 (24) found that when the coal is mixed with twelve and one half per cent. of lime and then coked, that a rather weak coke was obtained containing considerable calcium sulphide and sulphate. It may be interesting to note that on fusing some iron ore with this coke an iron of good quality was obtained and the slag contained considerable calcium sulphide. This was, however done in a crucible. No other literature with regard to the production of iron by the use of such coke, was found. But the use of lime is also noted by J. Alfred Wanklyn, in 1883 (25) and 1884 (26) in connection with the manufacture of gas. He calls the method the "Cooper's lime process." In the references given above he states the following as his con-



clusions from actual practice:- that the coke is a good quality of gas coke, that the amount of hydrogen sulphide in the gas has been reduced from eight or fifteen volumes to three and forty-four and two and forty-five hundredths volumes per thousand of gas, that the carbon bi-sulphide has been reduced from thirty or forty to eight and seven tenths grains per hundred cubic feet of gas, while an increase of thirteen per cent. in the yield of tar and thirty-six per cent. in that of ammonia was noticed. The expense of the line used is more than covered by the increase in yield of by-products. This process was used in England at the time the above articles were written. Whether or not the method has been used in America was not determined, for no other literature on the subject was found. John Fulton (27) claims that if sulphur is present in coal as calcium sulphide a large portion of it will be volatilized in coking. He, however, gives no authority and no results on which to base his conclusions. Another way of removing a part of the sulphur is by washing the coal used. This does not seem to have been tried, but we would expect to find the amount of sulphur decreased in both the gas and coke.

In looking over the statistics of the manufacture of coke in the United States it is found that Illinois produces less coke than any other coal producing state. Below are given two tables on the statistics of the manufacture of coke in Illinois (2).





Year	Estab- lish- ments	Covens		Coal Used	Coke Produced	Total Value of Coke at Covens.	Value of Coke per Ton.
		Built	Building				
1880	6	176	0	31240	12700	\$41950	\$3.30
1881	6	176	0	35240	14800	45850	3.10
1882	7	304	0	25270	11400	29050	2.55
1883	7	316	0	31170	13400	28200	2.10
1884	9	325	0	30168	13095	25639	1.96
1885	9	320	0	21487	10350	27798	2.68
1886	9	335	0	17806	8103	21487	2.65
1887	8	278	0	16596	9108	19594	2.13
1888	8	221	0	13020	7410	21038	2.84
1889	4	149	0	19250	11583	29764	2.57
1890	4	148	0	9000	5000	11250	2.25
1891	1	25	0	10000	5200	11700	2.25
1892	1	24	0	4800	3170	7133	2.25
1893	1	24	0	3300	2200	4400	2.00
1894	1	24	0	3800	2200	4400	2.00
1895	3	129	0	3600	2250	4500	2.00
1896	3	127	0	3900	2600	5200	2.00
1897	2	126	0	3591	1549	2895	1.87

Character of Coal used in the manufacture of coke in Illinois since 1890. The amounts are given in short tons.

Year	Run of Mine		Slack		Total
	Unwashed	Washed	Unwashed	Washed	
1890	0	0	0	9000	9000
1891	0	0	10000	0	10000
1892	0	0	4800	0	4800
1893	0	0	0	3300	3300
1894	0	0	0	3800	3800
1895	0	0	0	3600	3600
1896	0	0	0	3900	3900
1897	0	0	3591	0	3591



From the above we see that the production has been decreasing rapidly since 1891, also that no other than slack, and mainly washed slack, has been used for coking since 1890. Illinois certainly has considerable coking coal of an inferior grade. Unfortunately the better coking coals usually contain the higher per cent. of sulphur and vice versa. Of the numerous experiments made in washing the coal, none have been able to remove enough of the sulphur. However, wherever the best results have been obtained washed coal is used. Henry L. Luebbers (28), in 1874, claimed that slack coal had been washed in western Illinois for some time and after being pulverized and coked in retort ovens yielded a coke which is sufficiently dense for the blast furnace. He did not give any chemical analyses and made no statement as regards the kind of coal used. The report of the United States Geological Survey for (1894 - 1895) does not corroborate this statement, for, according to it, no coke, sufficiently strong and pure to be used advantageously in the blast furnace, had been made on a large scale in Illinois up to that time. In the last two years, however, considerable experimenting has been done, and from all reports probably some progress has been made too. One new process is called the "Hemingway Coking Process." In this process the ordinary bee-hive ovens are used, but instead of burning slowly, the combustion and coking are brought about rapidly by a blast of hot air. The inventor claims rapid coking with higher yield, and a good desulphurization. The process is employed by the "Universal Fuel Company," located at Thirty-fourth and Iron Streets, Chicago. They have built a plant of thirty bee-hive ovens of the new type and have experimented with numerous kinds of





coal. The product presents a good appearance and it is claimed that it finds a ready market. In coking some Connellsville coal at the Chicago plant, they obtained a twenty-four hour coke, which, from all appearances, was as good as a seventy-two hour Frick coke. . Although many claims are made by the inventor of the process as regards its value, still we have no analytical data to support nor to overthrow these claims. All that can be said from personal experience, is that the coke from some Danville and other lower grade Illinois coals, as made by the Chicago company possesses a good metallic luster and structure. Another interesting fact is that in the Hemingway process washed coal is also preferred.

Looking over what has been given we see that the washing of coals is an important item in the utilization of waste and other poor coal, also in the manufacture of gas and coke.

What does the washing of coal consist of? It is based on the difference in specific gravity of pure coal and mineral matter or very poor coal. In the washing the coal is brought in contact with a current of water or air, the lighter and purer carbonaceous material being carried away by the current. In most washers water is used. These we can classify into four different divisions, viz.:-

(a) Trough washer

(b) Jig "

(c) Percussion table

(d) Those washers in which a constant upward current of water effects the separation.

There are numerous washers in use, but the most effic-



ient and most used are of the second type. Of this type the Luhrig washer is best represented in Illinois. The Robinson washer, of the type given under (d), is also used extensively in this country, especially in the southern states. Without going into detail as regards the description of the mechanism of the two systems, we will simply outline the methods, noting the essential differences and give results obtained at some the largest washing establishments. Unfortunately we have no data on the comparison of the two washers, when the same kind of coal is being treated.

The Luhrig washer is really a form of the old Hartz ore jig, with the modification introduced by Mr. Carl Luhrig. This modification is that of having a layer of irregular pieces of feldspar on the screen, when fine coal is to be washed. In this process then, the coal is first sized before washing. The action of the jig is such as to give an intermittent current of water. This is certainly of great advantage in as much as flattened or elongated pieces are thereby afforded repeated opportunities of changing their positions and thus acquiring velocities more favorable to a classification according to density (30). The object of the feldspar on the screen, in the case of fine coal, is to afford a difficult passage for the coal and at the same time allow abundant opportunity for the action of the pulsating movement of the water. Many of the details in such a washer vary with the coal used.

The Robinson washer treats all the small sizes of coal in one operation; in it the coal is passed into an inverted cone-shaped vessel, where it is met by the constant ascending currents of water, the separation is assisted by the continual agitation





caused by stirrers. The good coal is carried upward and the heavier impure material falls to the bottom and is drawn off at intervals. In this washer we can say that the stirring takes the place of the pulsating movement of the water.

Below are given some of the results obtained by the Luhrig system. The per cents. refer to the washed and unwashed coal (12). The author does not state whether these results were obtained on the commercial scale or whether they were the results of hand washing.

No.	Location	Ash		Sulphur	
		Unwashed	Washed	Unwashed	Washed
		%	%	%	%
1.	Gloss Birmingham, Ala.	10.00	5.80	2.65	1.92
2	Sopris Sopris, Col.	22.48	7.20	.95	....
3	Big Muddy Carterville, Ill	14.25	4.50	1.14	.97
4	Blossburg Birmingham, Ala.	7.68	4.60	2.29	1.48
5	Mary Lee Birmingham, Ala.	10.32	6.14	.89	.71
6.	Belt Montana	29.69	7.35	4.32	2.40
7.	Toluca Toluca Ill	18.61	4.92	4.02	2.49
8.	Brazil Brazil, Ind.	24.32	5.67	....	....
9.	Rogers Lisbon, Ohio	12.78	4.90	3.14	1.27
10	Alexandria Greensburg, Pa.	10.60	5.00	1.14	.62
11	Cherry Valley Leeonia, O.	9.88	5.00	3.83	1.72
12.	Cornuc Union Bay, B.C.	35.50	8.50	2.15	1.30
13.	Sand Coulee, Montana.	25.59	7.25	4.24	1.87
14.	Cortidale Montana.	31.00	5.40	....	....
15.	Crabtree, Greensburg, Pa.	10.60	6.21	1.13	.617
16.	Atkins, Ohio	14.28	6.33	....	....



It is especially interesting to note that the coal from Crabtree (No.15 in above table) gave the following results when hand washed (18).

Size	Kind	Ash %.	S. %.	P. %.
1/8 in. to 3/8 in.	Unwashed	10.35	1.098	0.032
" " "	Washed..	6.88	0.604	0.025
1/16 " to 1/8 "	Unwashed	10.60	1.139	0.037
" " "	Washed..	6.213	0.617	0.025
Under 1/16 in.....	Unwashed	12.400	1.606	0.033

From this it appears that the analyses of the washed coal as given in the table on page fifteen were those obtained from hand washed samples, at least in case of sample, No. 15. Nevertheless the reliability of the process is well shown by the following example. The firm Cuninghame & Co. of Chicago, Illinois, who claim to control the Luhnrig patents in the United States and Canada made a contract with the Alexandria Coal Co. of Greensburg, Penn., "to erect for them at their Crabtree Mines a Luhnrig coal washery, having a capacity of six hundred tons per day of ten hours, and guaranteed to so cleanse the coal that in the coke made from the washed coal there should not be to exceed ten per cent. of ash or one per cent. of sulphur and that in the refuse there should not be to exceed one per cent. of available coal." The average results for a period of two weeks were nine and eighty-seven hundredths per cent. of ash and eighty-two hundredths per cent. of sulphur in the washed coal. The entire washery is operated by three men, the actual cost of washing the coal, when run-





ning at full capacity, does not exceed three cents per ton, and the washer is said to be able to thoroughly clean over six hundred and fifty tons per day of ten hours. Another interesting illustration of the removal of ash and sulphur by a Luhrig washer is the remarkable work at Kattowitz, Germany, where a coal containing forty-seven per cent. of ash, mainly pyrites, is washed down to five per cent. and the residue used for the manufacture of sulphuric acid, which pays the whole cost of treatment (31).

The results from the washing of coal at the Pratt Mines, Alabama, as found by J. J. Ormsbee (32), will serve to illustrate the quality of work accomplished by a Robinson washer. The table below will show most satisfactorily what is accomplished. In this table per cent. of volatile combustible matter includes per cent. of moisture.

Kind of Coal	Volatile Combustible Matter	Fixed Carbon	Ash	S
Slack before washing	29.55	60.36	9.98	1.48
Washed slack	30.69	63.51	5.78	1.25
Washed slack Over $\frac{3}{8}$ in. screen	31.01	63.82	5.16	1.27
Washed coal Under $\frac{3}{8}$ in. screen	29.54	61.75	8.52	1.40
Refuse from washer	15.02	24.93	60.05	1.99
48 hour coke from unwashed coal	.62	85.70	13.66	1.31
48 hour coke from washed coal	.54	89.04	10.43	1.13



Comparing these results with those obtained by the Lührig system, although not on the same coal, seems to indicate that both do about the same grade of work. However, the table also shows that the washing of smaller sizes of coal does not give as satisfactory results as if larger sizes are used, in this washer. The author states that the expense of washing the slack is more than counter-balanced by the higher yield in coke. The plant is capable of washing four hundred tons of coal per day at the expense of two and one-fourth cents per ton of coal.

As regards the work of washers in Illinois no careful experimenting in connection with analytical work seems to have been done. There are perhaps a dozen coal washing establishments in the state. Of these, at least one, the one at Braceville, which is a Howe washer, has been used for some twelve years. At De Soto and also at Carterville are Lührig washing plants. In this investigation washed and unwashed slack from the two last mentioned places were examined in connection with a number of other unwashed Illinois coals, which were sent to the University to be analyzed.

#### METHODS EMPLOYED.

##### Preparation of Sample.

No doubt the method of collecting samples could have been improved upon, but this could hardly be done without considerable expense. As it was, no systematic method for collecting the samples at the mines, car, etc., was employed. The size of sample varied considerably, but when once received at the laboratory it was broken up into pieces about the size of black walnuts, (if not already of that size or smaller), mixed, quartered and opposite





quarters taken. This grinding, mixing and quartering was repeated twice; after the last quartering the pieces of coal were small enough to be crushed readily on the bucking-board. About one-half a pint of the thus prepared coal was ground and all passed through a hundred mesh sieve, placed in Mason fruit-jar, sealed, and thoroughly shaken.

#### DETERMINATION OF MOISTURE.

The method recommended by the committee on coal analysis (33) was employed. Exactly one gram of the air dried sample was weighed in a porcelain crucible, dried in an oven at  $105^{\circ}$  to  $110^{\circ}$  C. for one hour, cooled in a desiccator and weighed as soon as possible. The only deviation was, that the crucible was not covered while weighing. No doubt this method is accurate enough for practical purposes, but according to W. E. Burk (34) some carbonaceous matter escapes at  $100^{\circ}$  C. and according to W. F. Hillebrand (35) and N. M. Austin (36) higher results are obtained by drying the coal in vacuo over sulphuric acid for twenty-four hours. The difference in the latter case is about thirty-seven hundredths of one per cent.

#### DETERMINATION OF VOLATILE COMBUSTIBLE MATTER.

Here the old method of heating exactly one gram of the air dried sample in a covered platinum crucible for three and one-half minutes with the ordinary Bunsen burner and, without allowing to cool, continuing the heating for another three and one-half minutes by means of a blast lamp, was employed. After cooling in the desiccator the crucible with contents and lid was weighed. .... The loss less the moisture gives the per cent. of vola-



tile combustible matter. According to the committee on coal analysis (33) this gives higher results than the amount obtained in practical coking. They recommend using an ordinary Bunsen burner for seven minutes. They also find that by heating rapidly, as is the case in these methods, there is no ash lost. Richard K. Meade and James C. Attix (37) find that the best way to obtain accurate results on coke is to heat the coke in an atmosphere of nitrogen or hydrogen. They also state that similar results can be obtained by heating the sample for seven minutes noting the loss in weight and repeating on the same sample. The second loss represents the amount first lost due to the burning of the carbon. The reasons the old method was employed in this study are, that a Bunsen burner flame is a very indefinite measure and second, that in all the previous work at the University the old empirical method had been used. Seven minutes heating with some Bunsen burners probably would not expell all the volatile combustible matter in some coals.

#### DETERMINATION OF ASH AND FIXED CARBON.

The method of burning the coal left from the moisture determinations was found the most satisfactory as it burned more readily than the coke obtained in determining the volatile combustible matter. This is the method recommended by the committee on coal analysis (33). The fixed carbon is determined by difference.

#### DETERMINATION OF SULPHUR.

Numerous methods have been proposed for the determination of the total sulphur in coal and coke, but by no means all







of them have been used to any extent. Below is given a classification which includes, most of the important ones, at least.

(1). Deflagration Method,

(2). Wet Methods,

(a) using  $\text{HNO}_3$  or  $\text{HNO}_3$  with  $\text{HCl}$ ,

(b) Carius method.

(3). Sintering Methods,

(a) Eschka's,

(b) Hundeshagen's,

(c) W. F. K. Stock's

(d) T. Nakamura's.

(4). Combustion in an atmosphere of oxygen.

The objections to the deflagration or fusion and also to the Carius methods are that in order to get accurate results all the iron and aluminium should be removed (38) as otherwise double and basic insoluble sulphate tend to precipitate. If, on the other hand, the iron and aluminium are first removed, the large amounts of salts formed by the fusion or by neutralizing the excess of acid will by no means be desirable. Evaporating to dryness to throw out the silica is not necessary according to R. W. Atkinson (46) and others, for the barium silicate is completely soluble in dilute hydrochloric acid, (47). In fact, by evaporating to dryness where gas, containing considerable sulphur is used as a source of heat, a large error is introduced, due to the absorbing of sulphur dioxide and possibly some sulphur trioxide, from the atmosphere of the room. That this is the case, is well shown by the work of E. von Meyer (48), Gunning (49), Alex (50), Wagner (51), Lieben (52), Privozink (52) and from personal experi-



once.

In Lunge's wet method, where the coal is treated with nitric acid or a mixture of nitric and hydrochloric acids, only the sulphur present as sulphide and soluble sulphate is determined (39).

The sintering methods are essentially alike. In each case the heating is carefully carried on until all the carbon is removed. In the Eschka (40) method sodium carbonate with twice the weight of magnesia is mixed with one gram of coal and then heated. In the Hundeshagen (41) method the sodium carbonate is replaced by potassium carbonate. In W. F. Stock's (42) method calcium hydrate only, is used, while in the Nakamura (43) method sodium carbonate only, is used. In each case the oxidation is completed by heating with sodium peroxide or ammonium nitrate, or by adding bromine water or a solution of hydrogen peroxide to the water solution or paste. Of these methods the Eschka and Hundeshagen are the ones that have been used most extensively. Hundeshagen claimed (41) that not all the sulphur was retained by sodium carbonate. This, however, is not the case as the results of J. O. Handy (44), G. L. Heath (45) and others show. G. L. Heath claims that Hundeshagen's loss was due to careless stirring of the very dusty Eschka mixture as compared with the more compact Hundeshagen mixture. In the sintering methods as well as in the fusions, there is danger of obtaining too high results due to the absorption of sulphur dioxide from the products of combustion of the gas, Price (54), Fresenius (55), Lunge (56), Hillebrand (57). In order to eliminate this error some authors have made the correction by a blank determination, while others have used an alco-





hol lamp for a source of heat. The objections to the former are that the blank will not be the same from day to day nor will all burners give the same factor. Using an alcohol flame is a tedious task. From this then, we see that all the methods described have their sources of error.

By the combustion of the coal in an atmosphere of oxygen all the sulphur and none other is obtained as sulphur dioxide or trioxide. By the addition of a little bromine this is all oxidized to the trioxide and subsequently precipitated as barium sulphate. W. Hempel (58) performs the combustion in a strong bottle, starting the combustion by the electric current as in the bomb. After the combustion, water and a little bromine are introduced and after all the vapors have condensed the solution is removed. The time required is about one hour. This method is accurate, but too expensive for ordinary purposes.

The method used in this investigation is the Eschka. An attempt was made to remove the sulphur compounds from the gas. In order to pass the gas through purifying solutions it was necessary to have it under a higher pressure than was maintained in the gas-mains. This was accomplished by connecting the exhaust of a water blast with the gas supply. Thus the gas was obtained under a sufficient pressure to pass through three washing solutions, each three or four inches in depth. The purifiers used, were caustic potash, alkaline hypobromite and lead acetate solutions. By no means all the sulphur was removed by this process. Next an alcohol blast was employed, but this could not be regulated well enough. Finally a G. Barthel gasoline heater was employed. The coal was mixed in a three inch porcelain dish with the dry



Eschka mixture, heated slowly at first and finally with occasional stirring heated to as high a temperature as could be obtained by the burner. It usually required two hours to burn off all the coal; in case of coke the time was about twice as long. On cooling, the sintered mass was transferred to a beaker with hot water, 15 c. c. of bromine water added and, after boiling for several minutes, filtered and carefully washed with hot water. To the filtrate were added about 10 c. c. of concentrated hydrochloric acid, the solution boiled, and after all the bromine was expelled the sulphate determined in the usual way. Several blanks were run and it was found that by heating the amount of Eschka mixture necessary for one gram of coal a correction of two tenths of a milligram of sulphur (or .02 % should be subtracted from the total per cent. of sulphur) was necessary due to the absorption of sulphur compounds from the air. A subtraction of .10 % from the total per cent. of sulphur was found necessary, to allow for the sulphur in the mixture and that absorbed. From this we see that the greater part of the correction was due to the comparatively impure mixture.

Although no work of any importance was done in this investigation with respect to the condition of the sulphur in the coal, still it may not be out of the way to note in this connection, Drown's method for determining the soluble sulphide and sulphate in coal (59), (60). It consists in treating the finely pulverized sample with 10 c. c. of a solution of sodium hydrate (of a specific gravity of 1.25) which has been saturated with bromine; then heating for ten minutes, acidifying with hydrochloric acid, again adding 20 c. c. of the hypobromite solution and





again heating, acidifying and repeating. After it has been made acid the third time it is evaporated to dryness and baked. The baked residue is extracted with water and hydrochloric acid, filtered, washed, and the sulphate determined in the filtrate. It is almost unnecessary to say that the method cannot give accurate results, for the influence of the large amount of sodium chloride formed, and the absorption of sulphur compounds from the laboratory atmosphere certainly are not favorable to the correctness of the method. Nevertheless Drown claims to have obtained accurate results in studying the behavior of sulphur in coal on coking, as given in the original article (19) and on page seven in this paper. In the article, Drown claims to have determined the sulphide only, by this method. The residue left from this treatment he burned in a current of oxygen, determining the amount of  $\text{SO}_2$  by passing the products of combustion through a standard potassium permanganate solution and titrating back. In the ash left after the combustion he determined the amount of sulphate present. He also determined the sulphate in the ash from the same coal without first applying his method for determining the sulphide. To his surprise he found much more sulphate in the latter than in the former method. This certainly shows that not only sulphide, but also some sulphate are removed by Drown's treatment.



TABLE OF ILLINOIS COALS  
ANALYZED IN THIS INVESTIGATION.

No	Received	Name of Coal.	Mine and Location.	Description
101	10-5-'44	Big Muddy.	De Solo, Ill.	Size No. 3, washed.
102	11-2-'44	"	"	Sludge from washer
103	"	"	"	Mine Run unwashed.
104	"	"	"	Size No. 1, washed.
105	"	"	"	" " 2, "
106	"	"	"	" " 4, "
108	12-'44	"	<sup>near</sup> Carterville	Unwashed lump.
110	3-7-'00	Danville	Danville	" "
111	"	Hubville Seam	"	" "
112	"	Murphysboro	Murphysboro	" "
113	5-8-'00	Big Muddy	Carterville	Mine Run unwashed.
114	"	"	"	Size No. 1, washed.
115	"	"	"	" " 2, "
116	"	"	"	" " 4, "
117	"	"	"	Next finer "
118	"	"	"	Finest from washer.

Samples 101 to 106 inclusive, were sent by the Big Muddy Coal & Coke Co.; 108 by the Sunnyside Coal Co.; 110 and 111 by H. W. Ross; 112 by the Quincy Gas Works, and samples 113 to 118 inclusive, by the St. Louis Big Muddy Coal Co. The sizes given for the washed coals do not agree in the two cases above mentioned, for the size of No. 101 was just about the same as of num-





ber 117 or size No. 3 of the Desoto coal corresponded to size No. 4 of the Carterville washer. Unfortunately no mud was received from the Carterville washer.

# COMPARISON OF WORK OF DESOTO AND CARTERVILLE WASHERS.

## DESOTO.

No.	Size Washed or Unwashed	% Moisture	% Volatile Combustible Matter	% Fixed Carbon	% Ash	Color of Ash.	% Sulphur.
103.	Mine Run	4.32	34.22	51.06	10.40	grayish red	1.45
	Unwashed	4.32	33.94	51.30	10.44		1.48
104.	No. 1	5.26	34.51	52.19	8.05	"	1.74
	Washed	5.29	34.75	51.89	8.07		1.72
105.	No. 2	4.33	35.50	51.88	8.29	"	2.11
	Washed	4.35	35.95	51.35	8.35		1.95
106.	No. 3	4.33	37.10	49.06	9.51	"	1.66
	Washed	4.31	36.42	49.75	9.52		1.75
106.	No. 4	3.90	35.92	52.22	7.96	"	2.16
	Washed	3.74	35.62	52.71	7.93		2.41
112.	Sludge from washers	2.95	22.58	28.84	45.73	grayish	2.83
		2.82	22.84	28.46	45.88		2.77

## CARTERVILLE.

113.	Mine Run	4.87	34.27	51.99	8.87	reddish	.861
	Unwashed	4.88	33.96	52.32	8.84		.851
114.	No. 1	4.55	33.97	54.21	7.27	grayish	.742
	Washed	4.77	34.01	54.20	7.02		.736
115.	No. 2	4.42	35.29	54.82	5.47	"	.877
	Washed	4.20	34.95	55.19	5.66		.858
116.	No. 4	3.95	34.77	52.94	8.34	"	.877
	Washed	4.00	34.55	53.14	8.31		.870
117.	Next finer	4.86	32.99	55.56	6.59	"	1.02
	Washed	4.86	33.53	55.02	6.59		1.09
118.	Finest	5.44	32.81	53.17	8.58	"	1.03
	Washed	5.57	33.14	52.83	8.46		1.09

Coke from 113 contained .38% S of the weight of the coal  
 " " 114 " .26% " " " " " " " "



It may be interesting to note that the sulphate found by boiling the ash of the DeSoto coals with dilute hydrochloric acid and precipitating as barium sulphate, gave the following per cents. of sulphur as soluble mineral sulphate in the coal.

¢ of S as SO <sub>2</sub>	.041	.054	.068	.065	.046	.261
	.043	.051	.070	.064	.046	.279
Number	103	104	105	101	106	102

These results vary in the same way as the total sulphurs with the exception of sample 106, which corresponds more closely to the relation shown in the ash determinations. That the sulphur determinations are at least relatively true is shown by the results obtained by using the calorimeter to be described later on. It is also interesting to look over the results obtained by evaporating to dryness before precipitating as barium sulphate. These last results very plainly confirm, what has been said previously on the danger of absorbing sulphur compounds from the laboratory atmosphere.

Co.	Evaporated to dryness before precipitating	Not evaporated to dryness	By Eschka's Method
10	3.58 4.38	1.75 1.44	1.66 1.75
102	4.55 4.61	2.33 2.40	2.83 2.77
103	3.46 4.43	1.50 1.69	1.45 1.48
104	5.55 2.23	1.36 1.32	1.74 1.72
105	2.34 2.23	2.14 2.17	2.11 1.95
106	2.43 2.40	2.22 2.29	2.16 2.41





On the whole we can say that the washing of these better grades of Illinois coal is not as successful as might be expected. This is especially true as regards the removal of the sulphur, the ash however, is lowered in each case. The fact that the sulphur is not lowered in each case, shows that the pyrites is very uniformly and finely scattered throughout the coal. The fixed carbon seems to be almost uniformly higher in the washed samples and the heating value also, as will be shown under the discussion on the calorimeter.

A thorough and systematic survey of Illinois coals with a special study of their behavior on washing would be of great benefit to the coal consumers. It would certainly be very interesting to wash some of the poorer grades of coal and compare the results with others. Illinois is the second coal producing and the last coke producing state in the United States, considerable can be done to increase the value of our coal deposits.



Through the kindness of the Urbana and Champaign Gas Co., a car load of the Carterville, No. 3 washed, coal was tested on a practical scale in the manufacture of gas. Two tests were made. In the first test of twelve hours 3 tons of coal were used, 3400 lbs. of brittle coke obtained, considerable tar and an average yield of 3.5 cu. ft. of gas per pound of coal. In the second test of twenty four hours the average results are, for each ton of coal 1190 lbs. of coke were obtained with a yield of 4.24 cu. ft. of gas per pound of coal. The candle power was about twelve. The Pennsylvania gas-coal then used at the works usually gave fairly good coke and a yield of 4.80 cu. ft. of gas per pound of coal. The candle power usually is about sixteen. Unfortunately the time was too short to make an accurate examination of the gas obtained from both kinds of coal.





No.	Location of Mine.	From (blow).	Date of Analysis	Proximate Analysis					Sample.	B.T.U. of air dried coal.	B.T.U. of combustible in coal.	Calorimeter used	Analyst
1.	Ladd			8.49	33.53	44.12	13.86			10790	13876		Porey th.
2.	"				36.70	48.20	15.10				14700		Carpenter U. of I.
3.	Spring Valley, washed screenings.		5-18-99	12.40	35.58	39.01	13.01		2.81				
4.	Assumption			3.90	41.20	50.10	4.80			13068	14313	L. Thompson	J. H. Clark.
5.	" Block			7.25	37.76	47.86	7.13		2.94				L. Smith
6.	" Lump			7.97	37.24	43.56	11.23		5.21				"
7.	Pana			7.22	36.37	46.95	9.46			11610	13934	L. Thompson	McConney
8.	Pana Black		3-25-98	8.55	35.45	39.35	16.65		4.77	9810	12980	"	U. of I.
9.	Inverton			13.30	30.40	52.00	4.30		.90	10588	12850		Emery, Chief of St. Louis.
10.	"			9.45	31.04	51.96	7.05		1.00	11234	13535		"
11.	Big Muddy			7.85	32.15	56.00	4.00			12825	14548	L. Thompson	J. H. Clark
12.	Astoria	Edenwood Coal Co.	1-6-98	12.26	40.00	39.40	8.34		3.16	11025	13885	L. Thompson	U. of I.
13.	Bryon average.	Whitebear Co.		2.42	32.91	42.64	22.03			9940	13157		Porey th.
14.	" select	"		3.85	38.05	48.75	9.32			11535	13634		Porey th.
15.	Buckhead average	"		6.14	29.94	46.27	17.65			10258	13427		Porey th.
16.	" select	"		8.92	33.52	48.06	9.50			11284	13538		Porey th.
17.	Canton average	A. W. Heald & Son		3.51	36.99	46.69	12.81			10945	13080		Porey th.
18.	" select.	"		4.40	38.32	48.09	9.19			11584	13405		Porey th.
19.	Clair average	Sunday Creek Coal Co.		3.16	32.94	43.05	20.85			9988	13142		Porey th.

Clinton Co.

Franklin Co.

Fullon Co.



No.	Location of Mine.	From (tham.	Date of (Analysis)	Moisture	Volatiles	Fixed Carbon	Ash	Specific Gravity	B.T.U. of an dried coal	B.T.U. of combustible coal	Collector	Locality.
Pellon Co. cont'd												
20.	Blaine select	Sunday Creek Coal Co.		5.27	37.30	48.21	9.22		11795	13797		
21.	Cuba average	W. Rutherford & Co.		4.17	36.38	48.62	10.83		11370	13376		Harvey Lk
22.	" select.	"		6.59	35.85	49.91	7.65		11582	13505		
23.	Cuba	Edmund Coal Co.	7-'98	10.42	36.93	40.96	11.69	4.60	10800	13864	L. Thompson	(C. of J.)
24.	Summit average	Whitehead Fuel Co.		2.46	32.91	45.57	19.06		10471	13342		Harvey Lk
25.	" select	"		3.54	37.59	52.37	6.50		12065	13411		
26.	" slack			9.64	28.86	39.48	22.02		9401	13756		
27.	Summitline	Edmund Coal Co.		10.95	34.80	36.54	17.71	3.13	10350	14508	L. Thompson	(C. of J.)
28.	"			9.60	28.90	39.50	22.00		9417	13768	Eng. Dept. of St. Louis	32
29.	Farming ton	Edmund Coal Co.	7-'98	11.22	35.93	36.60	16.25	3.98	10530	14518	L. Thompson	(C. of J.)
30.	" average	U.S. Pierce & Co.		3.41	33.88	45.89	16.82		10471	13126		Harvey Lk
31.	" select	"		6.17	35.96	48.49	9.38		11534	13657		
32.	Wiatl	Edmund Coal Co.	7-'98	12.54	35.86	40.04	11.56	4.67	10890	14347	L. Thompson	(C. of J.)
33.	St. David average	Carbon Coal Co.		2.00	34.60	46.20	17.20		10732	13399		Harvey Lk
34.	" select	"		3.07	35.88	52.59	8.46		11833	13376		
35.	" average	Whitehead Fuel Co.		1.50	33.77	47.67	17.06		11051	13569		
36.	" select	"		1.38	37.42	55.89	5.31		12384	13271		
Grundy Co.												
37.	Morris average.	A. H. Williams		7.10	32.12	49.74	11.04		10684	13052		Harvey Lk
38.	" select	"		7.49	35.19	54.45	2.87		12384	13815		
39.	Morris			6.45	30.86	52.82	9.87	3.32				
Hancock Co.												
40.	Augusta	Edmund Coal Co.	7-1 '98	10.78	44.37	41.32	3.53	2.48	11745	13706	L. Thompson	(C. of J.)





No.	Location of Mine	Thrombom	Date of Analysis	Proximate Analysis				Sulfur	B.T. U. of air dried coal	B.T. U. of combustible in coal	Calorimetric	Locality
				Moisture	Volatiles	Fixed Carbon	Clk					
41.	Blair Bluff			12.60	28.96	48.54	9.90					
42.	Galva	Elmwood Coal Co.	7-48	10.39	36.72	36.54	16.35	3.26	10080	13759	L. Thompson	U. of J.
43.	Kewanee			15.60	27.60	49.66	7.14					
Jackson Co.												
44.	Big Muddy	+		4.85	28.64	57.80	5.96	2.75				
45.	"			6.12	30.95	53.74	9.19	1.22	11529	13613		Eng. Club of St. Louis.
46.	"			6.35	31.50	55.25	6.90	2.02	12657	14590		Eng. Club of St. Louis.
47.	"			7.39	28.28	53.87	10.46	.98	11466	13757		"
48.	"			5.85	31.84	55.72	6.59	2.92	11781	13464		L. H. Smith.
49.	"			6.02	32.86	53.39	7.73	1.09				
50.	Carbonale			6.32	26.40	59.88	7.40					
51.	"			4.25	33.65	57.50	4.60		12582	13803	L. Thompson	Clark
52.	"		5-8-'96	6.08	39.78	46.22	7.92		11070	12572	"	U. of J.
53.	"		5-28-'96	6.18	34.10	49.12	10.60		11430	13734	"	"
54.	Kid'soto Mine Run	Big Muddy Coal & Coke Co.	11 '99	4.32	34.08	51.18	10.42	1.46				"
55.	" No. 1. washed	"	"	5.27	34.63	52.04	8.06	1.73				"
56.	" No. 2 "	"	"	4.34	35.72	51.62	8.32	2.03				"
57.	" No. 3 "	"	"	4.32	36.76	49.40	9.52	1.70				"
58.	" No. 4 "	"	"	3.82	35.77	52.46	7.95	2.28				"
59.	" Sludge from washer	"	"	2.88	22.71	28.65	45.76	2.80				"
60.	Met Carbon	+		6.37	31.93	59.13	1.81	.76				
61.	Murphysboro	Gas Works, Quincy, Ill.	3-1900	3.26	35.61	56.37	4.76	.76				U. of J.



No.	Location of Mine	From Whom	Date of Analysis	Proximate Analysis				B. & A.	A. & B.	C. & D.	E. & F.	G. & H.	I. & J.	K. & L.	M. & N.	O. & P.	Q. & R.	S. & T.	U. & V.	W. & X.	Y. & Z.
				Moisture	Volatile Combustible Matter	Fixed Carbon	Ash														
62.	Caesberg	Elmwood	20 98	9.31	36.05	34.64	20.00	3.90													
63	La Salle			5.22	39.70	43.15	8.43		12164	13444	13444	13444	13444	13444	13444	13444	13444	13444	13444	13444	13444
64	"	+		5.87	30.16	48.50	11.60	3.87													
65	By Clary			12.12	30.84	44.32	7.72														
66	Pearl			9.00	37.19	47.20	6.61		11529	13603	13603	13603	13603	13603	13603	13603	13603	13603	13603	13603	13603
67	Stratton average	Star Coal Co.		4.45	39.19	44.05	12.31		11399	13614	13614	13614	13614	13614	13614	13614	13614	13614	13614	13614	13614
68	" select.	"		2.16	40.20	54.97	2.67		13147	13814	13814	13814	13814	13814	13814	13814	13814	13814	13814	13814	13814
69	" average	C. W. & Co.		8.30	37.63	45.93	5.14		11476	13733	13733	13733	13733	13733	13733	13733	13733	13733	13733	13733	13733
70	" "	Coal Run Coal Co.		8.40	38.25	47.10	6.25		11727	13739	13739	13739	13739	13739	13739	13739	13739	13739	13739	13739	13739
71	Stratton.	+		6.87	29.11	49.70	11.20	3.12													
72	"			12.01	35.32	48.78	3.89	2.38	11420	13580	13580	13580	13580	13580	13580	13580	13580	13580	13580	13580	13580
73	" lump.				39.40	48.20	12.40														
74	" small				35.60	54.50	9.90														
75	" screenings.				31.40	42.20	26.40														
76	" "				39.60	45.40	15.00														
77	" "				38.40	43.80	17.80														
Lagan Co.																					
78	Lincoln			8.36	34.19	46.88	10.57	2.59													
79	"			8.45	34.99	44.50	12.06		11272	12963	12963	12963	12963	12963	12963	12963	12963	12963	12963	12963	12963
80	"			7.50	31.30	49.50	11.70		11718	14502	14502	14502	14502	14502	14502	14502	14502	14502	14502	14502	14502
81	"			10.92	27.60	46.64	14.84														
82	Mt. Pulaski			7.68	35.82	46.53	9.97		11360	13064	13064	13064	13064	13064	13064	13064	13064	13064	13064	13064	13064

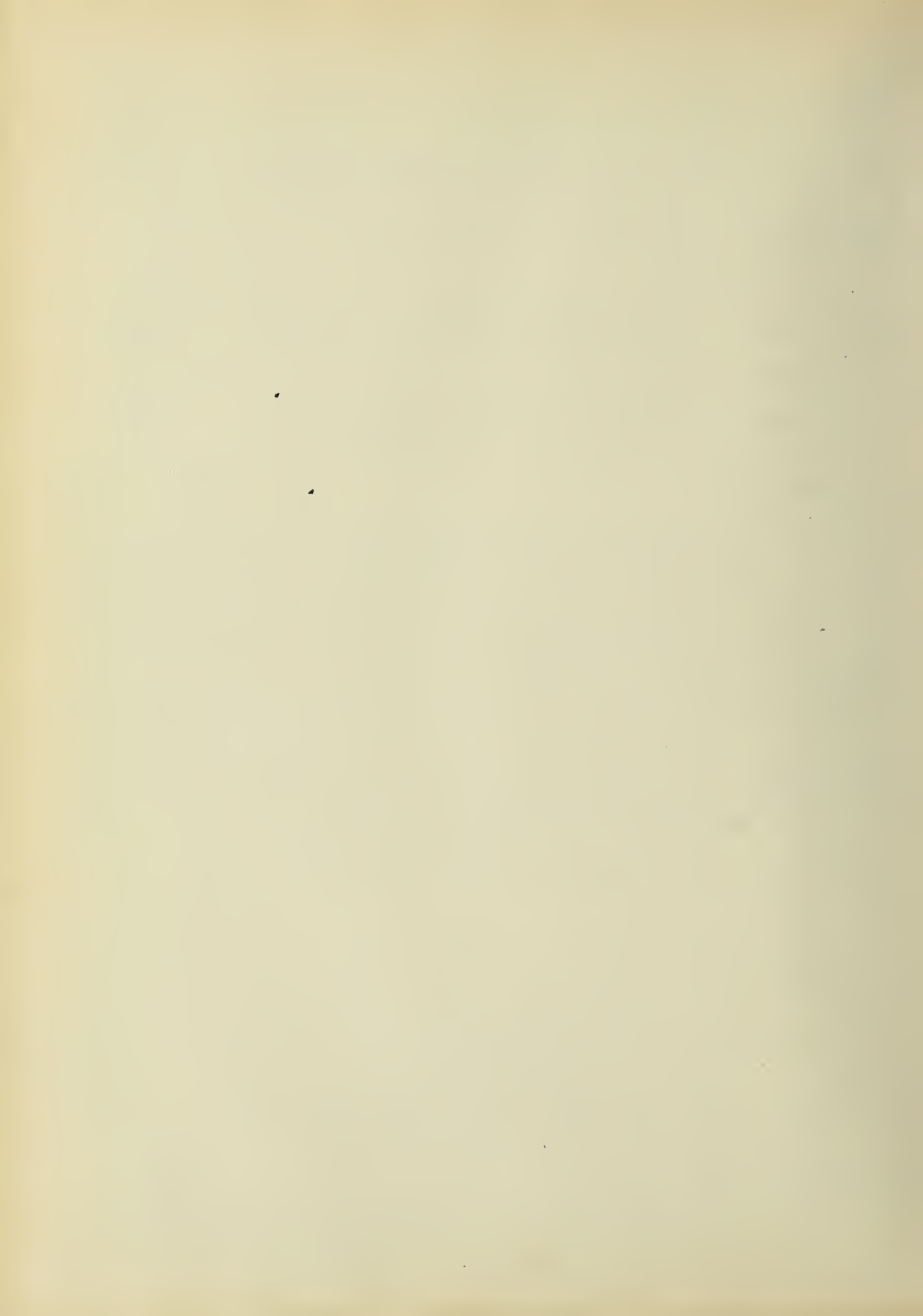




No.	Location of Mine	From Whom	Date of Analysis	Proximate Analysis				Moisture				Ash				Sulfur				Carbon				Iron				Copper				Zinc				Lead				Silver				Gold				Platinum				Nickel				Cobalt				Manganese				Potassium				Sodium				Magnesium				Calcium				Phosphorus				Chlorine				Fluorine				Bromine				Iodine				Barium				Strontium				Yttrium				Lanthanum				Cerium				Praseodymium				Neodymium				Promethium				Samarium				Europium				Gadolinium				Terbium				Dysprosium				Holmium				Erbium				Thulium				Ytterbium				Lutetium				Hafnium				Tantalum				Tungsten				Molybdenum				Niobium				Rhenium				Cadmium				Mercury				Bismuth				Antimony				Arsenic				Selenium				Tellurium				Polonium				Astatine				Radon				Francium				Radium				Actinium				Thorium				Protactinium				Uranium				Neptunium				Plutonium				Americium				Curium				Berkelium				Californium				Einsteinium				Fermium				Mendelevium				Nobelium				Lawrencium				Rutherfordium				Dubnium				Seaborgium				Bohrium				Hassium				Meitnerium				Darmstadtium				Roentgenium				Copernicium				Darmstadtium				Livermorium				Tennessine				Oganesson																																																																																																																																																																																																																																																																																																																																															
83.	Manito	Manito	1-6-95	4.41	34.25	40.55	20.74	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474	10706	14310	13259	14474



No.	Location of Mine	Date of Analysis	Fluoride analysis				Sulfur	B.T. U. of acid	B.T. U. of carbonate in acid	Calcium in acid	Locality
			Phosphate	Carbonate	Fluoride	Carbon					
Thames (cont.)											
103.	Edin Lump	2-23-95	6.32	37.73	44.45	11.50			1430	13659	E. Thompson
104.	"	2-10-96	4.10	36.41	47.22	7.22			11250	13554	"
105.	"	4-9-95	7.10	34.40	48.09	9.91			10980	13684	"
106.	"	6-11-96	5.09	37.93	42.30	14.68			11700	13528	"
107.	"	10-6-96	7.28	41.25	45.23	6.24			12240	14145	"
108.	"	11-6-96	7.24	40.76	45.77	6.23			12240	14578	"
109.	"	11-14-96	7.92	38.39	45.57	5.12			11520	14336	"
110.	"	11-27-96	8.11	35.73	44.62	11.54			11160	14574	"
111.	"	12-9-96	8.00	34.31	42.26	15.43			12330	14395	"
112.	"	1-26-97	3.50	38.30	47.35	10.85			11790	14655	"
113.	"	1-31-97	4.20	36.22	44.23	15.35			11790	15537	"
114.	"	2-4-97	5.42	34.03	41.55	15.70			11520	14355	"
115.	"	2-9-97	5.55	36.10	44.15	11.20			11520	14793	"
116.	"	3-29-97	7.71	35.43	42.44	14.42			10890	13378	"
117.	"	3-25-98	7.25	38.17	43.23	11.35	3.61		10946	13320	"
118.	"	3-6-95	6.32	37.73	44.45	11.50					
119.	"	'97	6.48	31.95	39.54	22.03					
120.	"	3-28-99	6.70	34.65	46.70	11.95	3.43				
121.	"	'94	4.70	33.78	46.05	15.47	4.80				
122.	"		6.07	33.99	50.86	9.08			11954	13747	E. Thompson
123.	"		5.90	41.10	46.90	6.10			12663	14389	"
24.	"	'97	6.48	31.95	34.54	22.03	4.31				E. Smith
25.	"	'97	6.81	37.05	44.23	11.91	2.68				"





No.	Location of Mine	From whom	Vol. of Unders.	Proximate Analysis				Sulfur	B.T. U of air drier	B.T. U of com. sample in case	Balance in case	Locality
				Moisture	Volatile	Fixed Carbon	Ash					
				Moisture	Volatile	Fixed Carbon	Ash					
26	Sanctoval			7.19	35.07	50.86	6.88	Tharion Co. (unrecorded)				
27	Joloca	Edmondson Coal Co.	7 98	8.95	33.07	41.32	16.66	4.64	10.800	14.518	"	U. of J.
				Tharion Co.								
128	Colchester	"	7-98	4.04	34.07	40.09	16.80	1.16	10.600	14.293	"	"
129	"	"		11.60	25.02	44.76	18.62		9.848	14.113	"	Eng. Dept. of St. Louis
130	" slack	"		5.30	25.48	38.12	31.10	1.20	9.035	14.207	"	"
				Mc Donough Co.								
131	Bloomington			7.90	34.02	53.12	4.96					
132	" Lump		98	3.80	43.90	43.50	8.80		11.970	13.695	E. Thompson	U. of J.
133	"			4.10	35.99	45.20	14.71		11.313	13.010	"	Mc Connery
				Mc Donough Co.								
134	Utthene			10.01	35.57	43.60	10.82	2.40				L. Smith
135	"		3-25-97	12.11	35.15	41.95	10.76		12.150	15.752	E. Thompson	U. of J.
				Tharion Co.								
136				8.40	31.20	54.80	5.60					
137	Wilchrist	Edmondson Coal Co.	7-98	7.48	36.94	35.32	20.26	4.86	10.620	14.696	E. Thompson	U. of J.
				Tharion Co.								
138	Edwardsburg	Harwell & Taylor Bros. O.B. Harman & Co.		3.20	35.48	47.77	13.55		10.945	13.147		Barryth
139	" average	"		1.90	34.48	43.62	20.00		9.940	12.726		
140	" select	"		5.04	33.96	49.56	11.44		11.051	13.530		
141	"	Harwell & Taylor Bros. Edmondson Coal Co.		4.08	38.24	52.17	5.51		12.037	13.310		U. of J.
142	Edmondson "66"		7-20-98	9.38	44.45	40.76	5.41	2.61				



No	Location of Mine	Where from	Date of analysis	Proximate analysis				Moisture	Volatile	Fixed Carbon	ash	Sulfur	B.T. (1. of air dried coal	B.T. (1. of combustible in coal	Remarks	Customer
Peoria Coal																
143	Elmwood, vein 3	Elmwood Coal Co.	7 98	8.70	43.63	41.30	6.37	2.75	12.420	14620	L. Thompson	U. of I.				
144	" " 5	"	"	10.55	36.78	42.30	10.37	1.29	11520	14560	"	"				
145	" " 6	"	"	9.30	35.50	43.90	11.30	3.16	11250	14160	"	"				
146	" average	"	"	1.36	27.69	35.41	35.54		8820	13978						Forsyth
147	" select	"	"	1.90	34.70	48.23	15.17		11051	13320						
148	"	"	"	7.60	27.60	55.30	9.50									
149	Lancaster	+	"	4.65	29.15	59.80	4.70	1.70								
50	Mapleton	+	"	5.05	29.24	59.02	4.95	1.74								
151	Peoria, average	Consolidated Coal Co.		3.22	36.13	49.21	11.44		11370	13323						Forsyth
52	" select	"		3.18	39.24	50.56	7.02		11845	13170						
153	Wattleson, average	Wattleson & Son		4.58	35.52	45.52	14.38		10790	13314						Forsyth
54	" select	"		5.51	35.92	49.76	8.81		11640	13580						
Ferris Coal																
155	Run Run			8.13	33.15	49.51	9.21	.83								L. Smith
156	"			8.86	23.54	60.60	7.00		10989	13800						
157	"			7.03	35.03	44.60	13.34		11128	13100						
158	" mud			7.43	38.91	46.00	7.66		12170	13995	L. Thompson	Mc Conney				
159	"			6.84	32.03	53.69	7.44		12393	14670	"	J. H. Clark				
160	"			6.67	30.35	54.08	8.90					U. of I.				
161	Runk		2-27-'95	7.43	39.81	45.10	7.66		11250	13500	L. Thompson	"				
162	"		9-29-'95	7.59	35.77	47.53	9.11		12060	14110	"	"				
163	"		6-15-'96	9.14	34.61	51.55	5.40		11050	14240	"	"				
164	" slack		5 11-'98	6.05	35.95	41.60	6.40	5.14				"				





No.	Location of Mine	From Whom	Date of Analysis	Proximate Analysis				Ash	Sulfur	3.7 % of acid coal	3.7 % of combustible in coal	Remarks	U. of I.
				Moisture	Volatiles	Fixed Carbon	Loss						
Perry Co. (cont.)													
165.	De Quoin		1-12-95	7.02	35.03	44.56	13.39		10989	13810	L. Thompson	U. of I.	
166.	" Jupiter			11.30	30.30	49.90	8.50	.90	10710	13351	Eng. Chert of St. Louis		
167.	Muddy Valley Lump	I. C. Coal & Salt Co.	7-25-96	7.11	40.37	48.23	4.29		11850	13408	L. Thompson	U. of I.	
168.	Paradise Lump	"	7-25-96	9.63	37.00	51.10	2.27		11970	13580	"	"	
169.	Paradise "		2-26-98	10.72	34.56	48.34	6.38		11700	14110	"	"	
170.	St. John			9.82	28.35	45.75	16.08	2.06	9765	13180	Eng. Chert of St. Louis		
71.	"			13.60	24.46	46.54	15.40	1.83	9828	13840	"	"	
Sangamon Co.													
172.	Theburn Screenings				37.50	47.30	15.20			13200	Carpenter		
173.	Barclay			7.40	35.70	46.20	10.70		11205	12886	L. Thompson	McConney.	
74.	"			10.08	27.32	45.60	17.00				U. of I.		
175.	Barren No. 33874		3-4-99	12.54	33.65	41.40	12.41	5.09					
176.	Dawson City		99	9.38	35.25	43.17	12.20	2.83					
177.	Louise.			10.71	37.62	45.07	6.60	2.39				U. of I.	
178.	Ridgely, Cal. No. 33224		2-25-99	9.41	36.94	41.44	12.21	4.09					
179.	" Bea		3-18-99	9.80	37.33	40.04	12.83	4.19				"	
180.	Riverton			11.06	37.94	42.98	8.02	3.27				U. of I.	
181.	"			6.38	35.39	48.45	9.78		11633	13378	L. Thompson	McConney.	
182.	"			11.10	38.45	44.30	6.15		12096	14610	"	J. H. Clark.	
183.	"	Springfield Iron Co.	3-25-99	8.83	36.51	40.56	14.10	4.22				U. of I.	
184.	Sangamon Lump		2-20-97	12.47	35.44	40.57	11.52		10980	14440	L. Thompson	"	
185.	Springfield			10.45	35.89	41.68	11.98	2.99				L. Smith	
186.	" Junction Mining Co.		2-16-99	9.11	37.04	43.52	10.33	3.65				U. of I.	



No.	Location of Mine	From Whom	Date of Analysis	Proximate Analysis				Sulphur	Ash and coal	B.T.U. of combustible matter	Calorimeter used	Corrected
				Moisture	Volatile	Fixed	Ash					
187.	Rushville	+		6.00	31.60	52.90	6.50	3.00				
188.				7.17	37.00	42.09	13.74		10383	13120		
189.	Maverqua Lump		1-19 '95	9.18	39.58	43.75	7.49		11700	14040	L. Thompson	U. of I.
190.	" Lump Rein		12-13-'95	5.77	36.57	45.57	9.09					"
191.	" " 2		12-13-'95	7.08	42.80	42.14	7.98					"
192.	" " 5		12-13-'95	8.00	39.53	46.00	6.47					"
193.	Combardville			Star Co.								
				4.42	31.38	51.74	7.46					40.
				St. Clair Co.								
194.	Belleville	+		7.05	29.95	50.40	9.50	3.10				
195.	Meity Bluff			8.95	37.81	48.24	5.00	3.30	10332	12015		Eng. Club of St. Louis
196.	Johnson			5.50	40.41	40.26	13.83	4.80				Eng. Club of St. Louis
197.	Oakland			8.30	34.40	43.12	14.18	4.42	10395	13410		Eng. Club of St. Louis
198.	Reincke			7.56	39.81	42.49	10.14	4.02				"
199.	Vulcan mt			7.44	30.86	45.09	16.61	1.30	4450	12435		Eng. Club of St. Louis
200.	"			10.30	27.90	49.00	12.80	.70	10625	13817		"
				Vermillion Co.								
201.	Danville	+		6.40	30.11	51.12	9.25	3.12				
202.	"			4.78	43.70	45.37	6.15		12506	14382	L. Thompson	McComey
203.	"			5.62	37.07	46.43	10.88		11655	13403	"	"
204.	"			11.00	32.35	53.00	3.65		12285	14390	"	J. H. Clark
205.	" Screenings		5-25-'96	9.40	33.30	34.20	23.10		9360	13860	"	U. of I.





No.	Location of Mine.	Thom U-horn.	Date of Analysis.	Proximate Analysis				Sulfur	B.T.U. of air dried coal	B.T.U. of semibituminous coal	Calorimeter used	County
				Moisture	Volatile	Fixed Matter	Carbon	Wet				
				Perrin Co. cont.								
206.	Danville	Ho-Ross	3-7-60	7.56	47.47	40.50	4.47	3.62				U. of S.
207	" Westville Seam	"	"	8.06	40.64	47.37	3.93	1.27				"
208	Parrington Screenings		12-10-96	10.67	36.46	39.85	13.02		10890	14270	E. Thompson	"
209.	"			8.10	31.80	47.05	13.05		11431	14490	"	J.H. Clark.
210	Grope Creek			9.74	28.34	51.32	10.60					
211	Oakwood			7.80	37.55	46.00	8.65		12528	14990	E. Thompson	J.H. Clark
				U. of S. Co.								
212.	Bilington	+		7.12	28.77	49.46	11.25	3.40				
213	" Cumberland			36.80	49.90	13.30				14050		Carpenter
214.	" Screenings			32.60	39.70	27.70				13200		"
215.	" Washed "			34.50	50.20	15.30				14200		"
				Fellman Co.								
216.	Cartersville Mine Run	St Louis Big + Muddy Coal Co.	5-12-00	4.87	34.11	52.17	8.85	.85				U. of S.
217	" No. 1, washed	"	"	4.66	33.99	54.21	7.14	.74				"
218	" No. 2,	"	"	4.31	35.12	53.01	5.56	.86				"
219	" No. 3 "	"	"	3.98	34.66	53.04	8.32	.87				"
220	" No. 4 "	"	"	4.86	33.26	55.29	6.59	1.15				"
221	Dual from washer	"	"	5.50	32.97	53.01	8.52	1.16				"
222	Cartersville No. 2 Washed Screenings		3-25-98	5.76	30.25	57.32	6.67	1.18	12420	14180	E. Thompson	"
223	"		"	7.35	34.20	52.34	6.11	1.05				"
224	Lake Creek		"	3.42	39.30	53.20	4.06	1.72	12240	13230	E. Thompson	"



A NEW METHOD FOR  
DETERMINING THE CALORIFIC VALUE OF COALS.

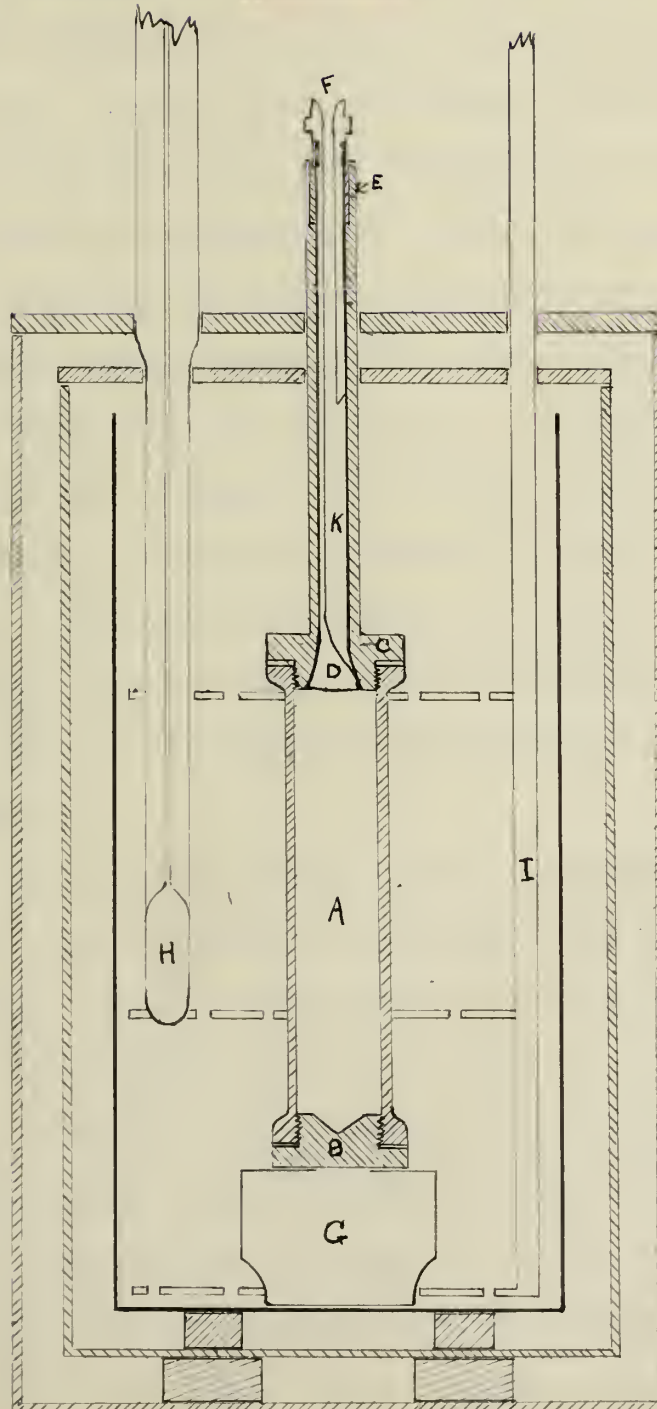
Of all the calorimeters used in commercial work in this country the Lewis Thompson is perhaps, most generally known. The oxygen is furnished by the decomposition of a mixture of potassium chlorate and nitrate, with which the coal is previously mixed. The decomposition is brought about by igniting the mass when outside the calorimeter jar of water. It is unnecessary to say that such a crude method can hardly give accurate results. However with some skill, experience and patience, fairly concordant results can be obtained providing the loss in heat is not too great, due to too rapid or incomplete combustion. If the combustion is too rapid, much of the coal is thrown out of the cartridge and the gases rapidly passing through the water also carry off heat units. The rapid combustion can be retarded by using more of the calorimeter mixture, as has been stated by Prof. S. W. Parr (61). In no case is the combustion entirely satisfactory. The results, in order to be at all reliable, must be increased by fifteen per cent. as Scheurer-Kestner determined (62). It was in order to bring about a more complete combustion that Prof. Parr, in 1896, (61) added some sodium peroxide to the mixture used in the Thompson calorimeter. The combustion was complete and more uniform readings were obtained. He obtained an increase of 360 to 400 B. T. U. by using one-half gram of sodium peroxide as stated. This increase was due to the absorption of carbon dioxide and water formed by the combustion. Even if a perfect combustion is obtained, still the errors involved are numerous and the method





should not be used if it can possibly be avoided.

If sodium peroxide aids the combustion, why not use it alone? It can be used alone, and after numerous experiments as regards apparatus, manipulation, and condition of coal and sodium peroxide, the calorimeter, of which a sketch and description are given below, was devised by Prof. Parr.





The outer jacket of this calorimeter is of the same kind of material as that of Dr. Atwater's apparatus, namely of indurated fiber. The jar is a nickel plated copper or brass can, large enough to hold two liters of water. Inside this can are placed, the brass stirrer I, which is run by a water-motor, the thermometer H, the brass stand G, and the bomb A, also of brass. The bomb, as we see, consists of a piece of brass tubing with a thread cut into each end. At the lower end is the solid plug B, at the upper is the fitting which has the contrivance by means of which a red hot wire, about one quarter of an inch long, can be dropped into the bomb. This is so arranged that when F is pressed downward, D is lowered enough to allow the wire to pass between it and C, after having come down the channel K. The spring at E serves to bring D back to the original place when the hand is removed from F. The stand G, is used in order to allow the water to circulate under the bomb and at the same time reduce the error due to conduction of heat from the bomb. The best thermometer used was a differential mercury thermometer, graduated to hundredths of one degree Centigrade.

To prepare the combustible for the bomb it should be dry (oven dry), very finely divided (100 mesh), and mixed with enough of the fine sodium peroxid (fine enough to pass through a millimeter sieve). The mixing is brought about by introducing the combustible and peroxide into the bomb, closing the same well and, while holding F so that D will remain closed, shaking thoroughly. Finally after a good shaking the bomb is tamped so that practically all of the mixture is removed from the upper part of the bomb. The bomb is now placed in the required amount of water,





the temperature of which is as much below that of the room as one half of the total increase in temperature due to the combustion of the substance to be tested. By stirring a fairly uniform temperature of the water is obtained; the temperature is then noted, the red hot wire introduced as given before, and the stirring continued. If the temperatures are properly chosen the highest reading is taken and the increase gives the data for calculating the heat of combustion by using sodium peroxide.

However, as stated before, the increased reading over that of the true combustion of the substance is due to the absorption of the carbon dioxide and water. That all carbon dioxide is absorbed is shown by the fact that practically no pressure is noticed on the inside of the bomb during a combustion. A correction factor for this absorption had not been previously determined.

The most ready method that suggested itself for determining the heat of absorption of carbon dioxide is by the use of sugar carbon. By burning some sugar carbon in the above bomb and noting the heat developed, we have from five combustions the following results:-

Carbon taken.	$\text{Na}_2\text{O}_2$ taken.	B.T.U. observed.
1 grm.	17 grms.	18951
"	"	18915
0.5 grm.	8.5 grms.	19094
"	"	18720
"	"	18971

However, this same sugar carbon when burned in the Mahler bomb gave only 13891 B.T.U. as the average of four readings. Accepting 14500 as the correct figure for the B.T.U. of pure carbon, this shows that the carbon used was by no means pure. This being the



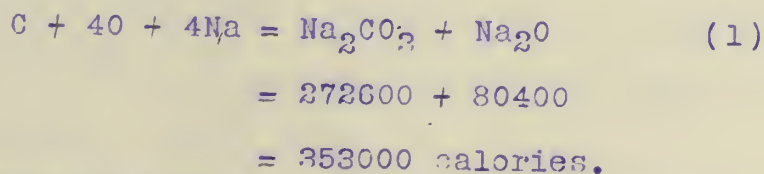
the purest at hand and time being limited a correction for impurities was obtained as follows. Rather roughly speaking we may say that one gram of the carbon used represents  $\frac{13891}{14500}$  or .9580 gram of pure carbon. This includes, of course some small elements of error which will not materially affect the present case. According to this then the reading with pure carbon when burned in the peroxide bomb should be  $\frac{18931}{9580}$  or 19760 B.T.U. This then means that the correction factor for the absorption of carbon dioxide is  $\frac{19760 - 14500}{19760}$  or 26.67%.



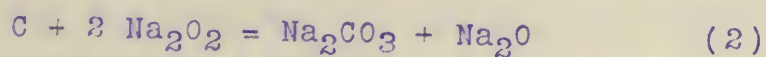


The next task was to obtain the heat of absorption of the water formed in the combustion of hydrogen containing substances. We first attempted to do this by burning naphthalene, but we could not obtain a perfect combustion. Next anthracene was tried with the same results. Benzene also could not be burned completely, a layer of lampblack and an oily substance being formed on the walls of the bomb in each case. Next more complex substances namely sugar, and tartaric, benzoic and citric acids were used. In each case good combustions were obtained and also good duplicate readings. However, these could not very well be used for this calculation, on account of the unknown behavior of the carbon and hydrogen in the combustion of such substances. Water also, was tried in various ways and at one time quite concordant readings were obtained, but they were not reliable, as in no case were we able to bring about an absorption which seemed perfect. Finally the experimental method was dropped and taking the absorption factor of the carbon dioxide as correct we calculated that of the water.

In the formation of sodium carbonate and sodium oxide from the elements we have the following.



when gram molecules are taken. In the same way when the carbon is burned by using sodium peroxide, we have the same products.



From our determination we find that one gram of carbon gives

$$8080 \div (1.00 - .2667) \text{ or } 11018 \text{ calories.}$$



One gram molecule then gives

$$11018 \times 12 = 132216 \text{ calories.}$$

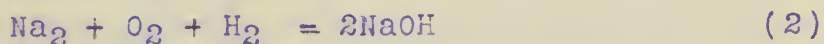
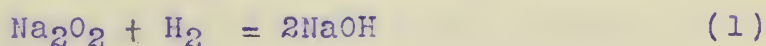
That is, from the two equations above we find that

$$(353000 - 132216) \text{ or } 220784 \text{ calories}$$

were required to decompose two gram molecules of sodium peroxide, or in other words the heat of formation of sodium peroxide is

$$1/2 \text{ of } 220784 \text{ or } 110392 \text{ calories.}$$

Knowing the heat of formation of sodium peroxide, we can readily calculate what is the heat of absorption of water.



In (2) we know that the heat of formation of 2NaOH is

$$102700 \times 2 \text{ or } 205400.$$

In (1) the same amount of the same product is formed, but one gram molecule of sodium peroxide must be decomposed. This decomposition requires the same amount of heat as the heat of formation, which is 110392 calories. Then in (1) we would have a reading which is 110392 calories lower than 205400, or 95008 calories.

In other words the heat of combustion of two grams of hydrogen by means of sodium peroxide gives a calorimetric reading of 95008.

But the combustion of two grams of hydrogen by means of oxygen gives 68360 calories. Then

$$(95008 - 68360) \text{ or } 26648 \text{ calories}$$

represents the amount of heat liberated due to the absorption of the water formed in the combustion. Then, in order to obtain an accurate reading for the combustion of hydrogen in the Parr calorimeter we must subtract

$$26648 \div 92272 = 28.87\%$$

$$95008 - 28.87\%$$



THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL

THE CHINESE JOURNAL



of the reading obtained, from the reading.

Every coal contains besides carbon some "disposable" hydrogen. The per cents. of "disposable" hydrogen and of carbon vary in different coals and on first thought we might suppose, that a different correction factor would be necessary for each coal. If so, then this method would hardly be of any value. But with the two combustibles, carbon and hydrogen, so close in their absorption factors viz.,

26.67% and 28.87%

respectively, a common factor for the two seems possible. This is even more evident if we take into consideration the relatively low per cent. of "disposable" hydrogen present in coals. The uniformity of this common factor is well illustrated by the following table in which the amount of "disposable" hydrogen varies from one to ~~seven~~<sup>six</sup> per cent. and the carbon, from sixty to ninety.

H %	C %						
	90	85	80	75	70	65	60
1	26.72	26.72	26.72	26.73	26.74	26.74	26.76
2	26.78	26.78	26.78	26.79	26.80	26.81	26.82
3	26.82	26.82	26.82	26.83	26.84	26.85	26.86
4	26.86	26.86	26.86	26.87	26.88	26.89	26.90
5	26.95	26.95	26.95	26.96	26.97	26.98	26.99
6	27.00	27.00	27.00	27.01	27.02	27.03	27.04

From this we see that the common correction factor varies from 26.72 to 27.04% or a greatest difference of .32%. As would be expected, a slight increase in the per cent. of hydrogen makes a much greater change in the correction factor than the same or even five times greater increase in the per cent. of carbon.

of the ... ..

... ..

... ..

... ..

... ..

... ..

... ..

... ..

... ..

... ..

... ..

... ..

... ..

... ..

... ..

...

...

...

...

...

...

...

...

... ..

... ..

... ..

... ..

... ..

The ratio of carbon and hydrogen in coals is however fairly uniform. A general average, being 80% of carbon to 4% of hydrogen; of these two the hydrogen very seldom varies by more than one per cent. in either way. Even if a greater deviation is noticed, the error in using a constant common factor (say 26.86% for 80% of carbon and 4% of "disposable" hydrogen) would be approximately .16% in either extreme. Taking the average total indication of 17000 B.T.U., then an error of .16% in the correction factor would be about 27.2 B.T.U., which is well within the experimental error.

In addition to the above correction may be mentioned that for the absorption of the water of combination in the coal. The hydrogen present as non-disposable is usually about one per cent. One per cent of hydrogen if burned in the peroxide calorimeter would generate 475.04 B.T.U., but as this hydrogen is already oxidized we take into consideration only the heat of absorption of the water. This being 28.87% of the total heat developed in the combustion, we have 137.14 B.T.U. to correct for. Making a calculation on a coal having 80% of carbon, 4% of "disposable" and 1% of "non-disposable" hydrogen we obtain a correction factor of 27.83% of the total reading.

Below is given a table in which are tabulated the results obtained by burning various kinds of coal in the Atwater, Mahler and peroxide bombs. The correction factor used is 27.00%.







Kind of Coal	Ultimate Analysis					B.T.U. per pound - air dry		
	Hydrogen	Volatiles Combustibles in %	Fixed Carbon	Ash	Sulfur	Combustion Calorim.	Heat Calorim.	Correction from Combustion Calorim. 7.00%
26 Eastern Mine Run	4.87	34.	52.17	8.85	.85	12203	12214	-.07
217 Washed #1	4.06	33.49	54.21	7.14	.74	2289	2286	.00
218 Washed #2	4.31	35.2	55.01	5.56	.87	12914	12934	+.08
220 Washed #4	4.56	33.26	55.29	6.57	1.15	2333	2345	-.08
221 Dust from washer	5.50	32.97	53.01	8.52	1.16	12384	12336	-.39
226 Edge Hill "A" Coal	7.27	35.76	42.96	14.01	3.84	11025	11064	+.35
227 Birmingham Mine Run	11.22	35.93	36.60	6.25	3.98	9986	10018	+.32
228 Penn. Gas Coal	.92	36.66	58.94	3.46	1.40	14270	14275	.00
229 Kentucky? Sunnyside Coal	.94	32.33	34.35	32.33	1.07	10313	10328	+.14
230. Miss issippi	14.56	43.82	29.30	2.32	—	8316	8378	+.74

In general we may say that 27.00% seems the most satisfactory correction factor. There is no doubt as regards the reliability of the results obtained by this instrument. It has the great advantages of being rapid, accurate, simple and comparatively inexpensive.



## REFERENCES

	Vol.	Year	Page
(1) Mineral Industry.....	6	1893	165
(2) Min. Res. of U. S.....		1897-'98	
(3) Cass. Mag.....	10	1896	298
(4) Report on "Waste of Coal Mining in Penn.".....		1893	
(5) " " " Do.....		1893	152
(6) Cass. Mag.....	9	1895	3
(7) Eng. Mag.....	11	1896	645
(8) Jour. Frank. Inst.....	142	1896	26
(9) " " " ".....	146	1893	357
(10) Cass. Mag.....	13	1898	354
(11) " " " ".....	12	1897	581
(12) Trans. Am. Soc. Mech. Eng.....	18	1896	
(13) Compt. Rend.....	88	1897	590
(14) Dingl. Polyt. Jour.....	256	1885	222
(15) Fischer's Jahresbericht.....		1887	113
(16) " " " ".....		1890	630
(17) Berg. u. Huttenm. Ztg.....		1893	96
(18) Trans. Am. Inst Min. Eng.....	8	1880	201
(19) " " " " " ".....	9	1881	662
(20) Bolley & Birnbaum.....	( Vol. 1 ( Group 3 ( Part 3		524
(21) Coke by John Fulton.....		1895	30
(22) Min. Res. of U. S.....		1895-'96	577
(23) Thesis by L. Smith, 1897, U. of I. "Suitability of Illinois			



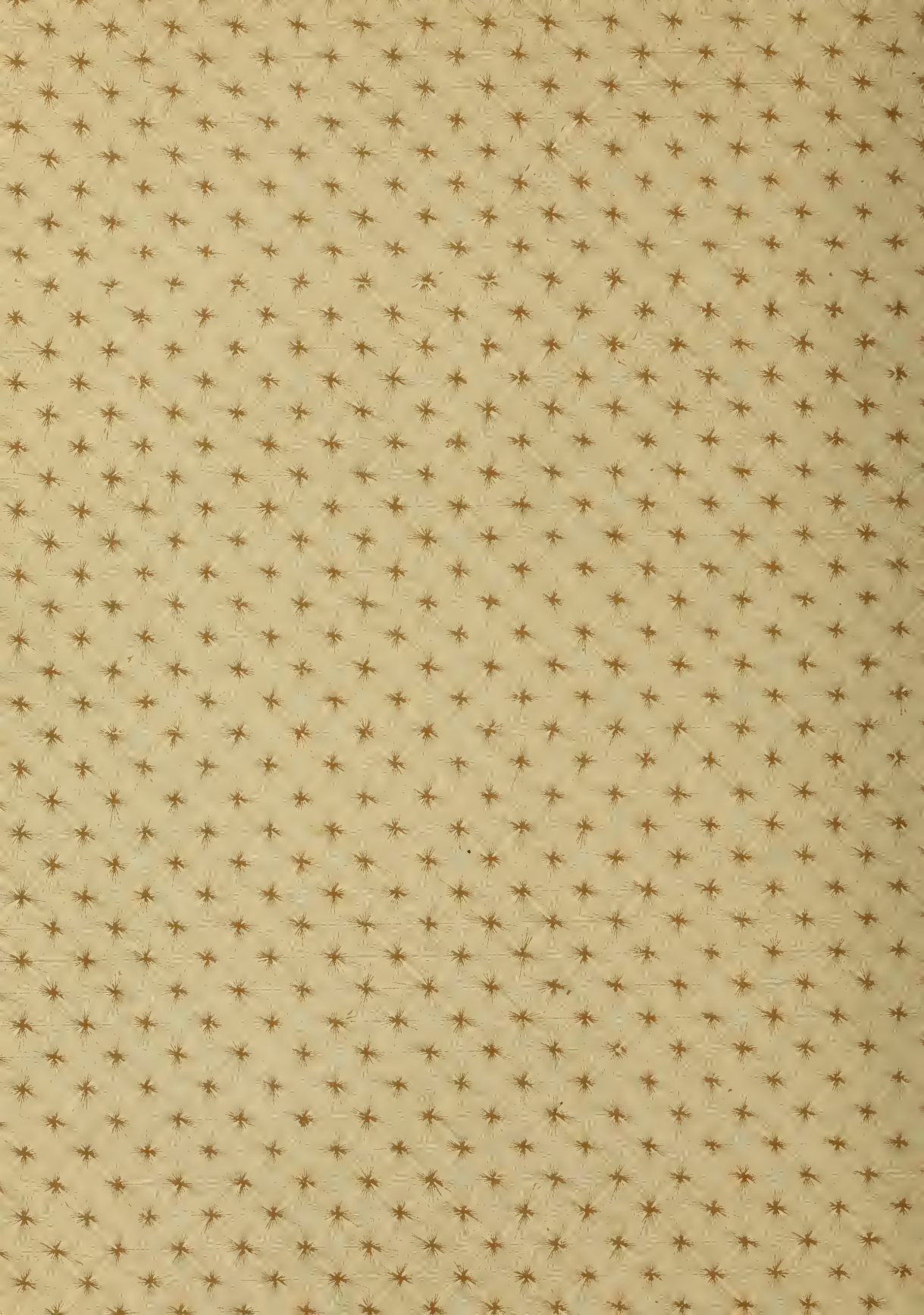


	Vol.	Year	Page
Coals for Gas Making".....			
(24) Trans. Am. Inst. Min. Eng.....	8	1880	200
(25) Jour. Soc. Chem. Ind.....	2	1883	440
(26) " " " " .....	3	1884	12
(27) Coke by John Fulton.....		1895	34
(28) Trans. Am. Soc. Civ. Engs.....	2	1874	163
(29) Jahr. Ber. Chem. Tech.....	40	1894	20
(30) Trans. Am. Inst. Min. Eng.....	9	1881	461
(31) Jour. Soc. Chem. Ind.....	10	1891	984
(32) Trans. Am. Inst. Min. Eng.....	25	1895	113
(33) Jour. Am. Chem. Soc.....	21	1899	1126
(34) Proc. Indiana Academy of Scs...		1896	113
(35) Jour. Am. Chem. Soc.....	20	1898	282
(36) " " " " .....	21	1899	1116
(37) " " " " .....	21	1899	1137
(38) " " " " .....	21	1899	772
(39) Zeit. Anal. Chem.....	27	1888	445
(40) Chem. Centrall Blatt.....	( 3 Folge 5	1874	301
(41) Chem. Ztg.....	16	1892	1070
(42) Jour. Soc. Chem. Ind.....	5	1886	154
(43) " " " " .....	5	1886	154
(44) Jour. Anal. & App. Chem.....	6	1892	116
(45) Jour. Am. Chem. Soc.....	20	1898	632
(46) " " " " .....	21	1899	1129
(47) A. M. Comey's.....		1896 Ed.	363
"Dictionary of Chemical Solubilities"			

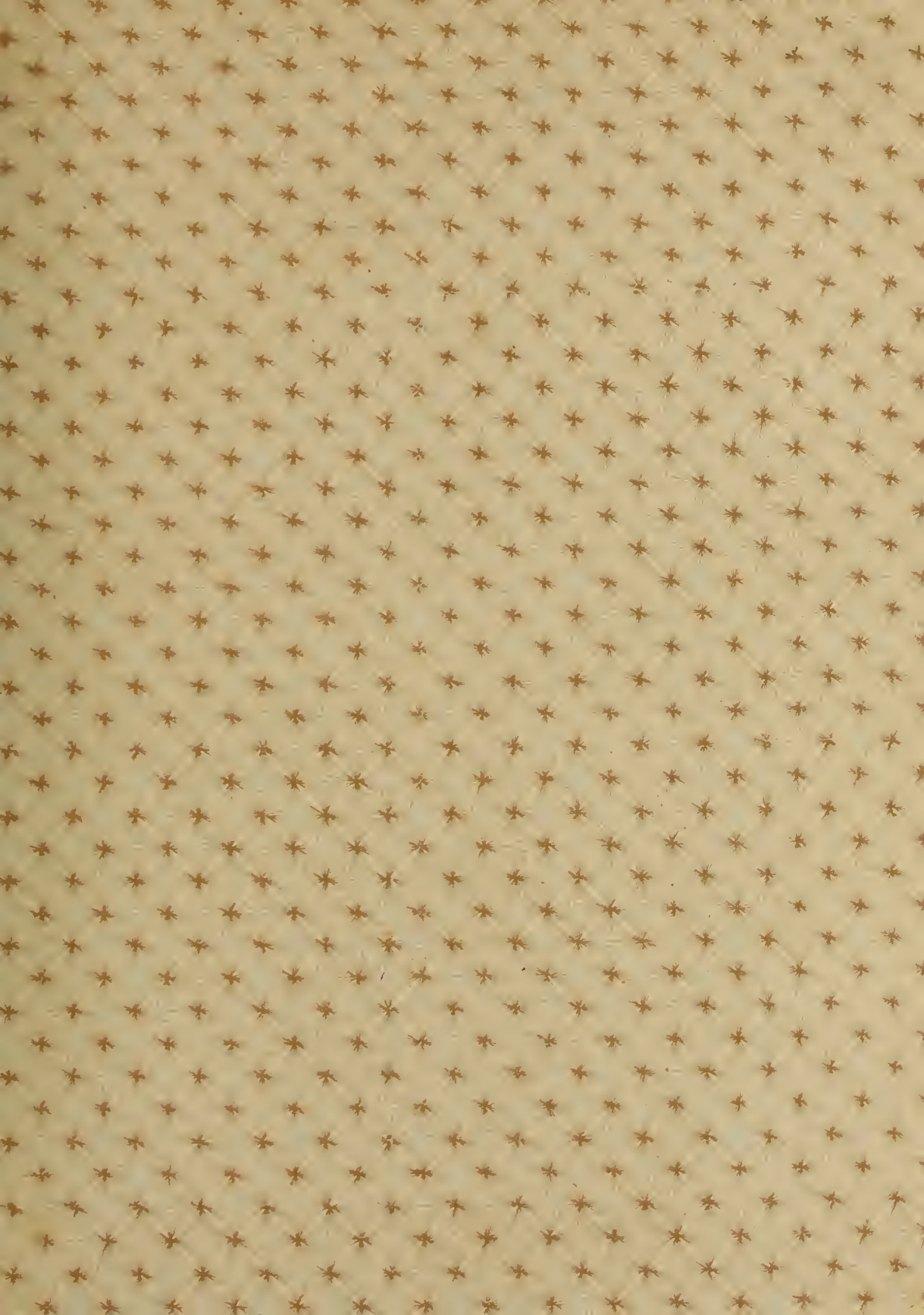


	Vol.	Year	Page
(48) Jour. Prakt. Chem.....	42	1890	270
(49) Zeit. Anal. Chem.....	7	1868	480
(50) " " " .....	10	1871	246
(51) " " " .....	20	1881	323
(52) " " " .....	32	1893	214
(53) Berichte.....	25	1892	2200
(54) Jour. Lond. Chem. Soc.....	2	1850	51
(55) Zeit. Anal. Chem.....	16	1877	339
(56) Jour. Prakt. Chem.....	40	1889	239
(57) Bull., No. 145, U. S. Geol. S..		1897	
(58) Zeit. Ang. Chem.....	6	1892	393
(59) Trans. Am. Inst. Min. Eng.....	8	1880	569
(60) Chem. News.....	43	1881	89
(61) Technograph.....	11	1896-'97	89
(62) Jour. Soc. Chem. Ind.....	7	1888	369

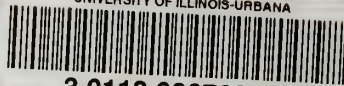








UNIVERSITY OF ILLINOIS-URBANA



3 0112 086762017